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Functional Test Results of a High Power Patch Array Antenna

by Canh Ly

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14. ABSTRACT
Mechanical and electrical test results of a high power two-patch array antenna [ARL Invention pending ARL-07-18, Ly, et al.] are presented. The mechanical test was run for 55 minutes for each axis of the antenna. The electrical test was conducted using a high power RF source (>1 KW) with single and two-patch array antennas. Although the first mechanical test results indicated that the screws of the antenna cover are loosened about 1/4 turn, and right angle connectors inside the antenna enclosure box were loosened about a fraction of a turn, the antenna still sustained all functional operations. The antenna uses air dielectric to endure a high average power for the system that operates at S-Band in order to neutralize unattended microwave devices. This development is to fulfill part of the Army Technology Objective (ATO), Network Centric Warfare for the U.S. Army Communications-Electronics Research, Development, and Engineering Center (CERDEC), and Research and Development Engineering Command (RDECOM).

15. SUBJECT TERMS
Patch array antenna, vibration test, high power

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1. Introduction

High power microwave systems will be critical to future Army neutralization systems that have the capability to defeat and neutralize unattended improvised explosive devices (IED) on the modern battlefield. Highly efficient and high power handling antennas will be required for these systems. The U.S. Army Research Laboratory has developed an efficient antenna array (*1*) that can handle high power (> 1 Kilo Watts (KW)) radio frequency (RF) using pulsed or continuous waveform (CW) sources. The initial radiating element was developed and modeled by Weiss and Coburn (*2*,*3*). Ly (*1*) extended the single element to a two-patch array antenna. In particular, correct dimensions for the antenna design have been experimentally determined to obtain optimal performance and integrated in an enclosed metal box. The high power two-patch array antenna operates at S-band with the bandwidth of 420 MHz with ±210 MHz from the center frequency. This report presents the results of electrical and vibration tests for the high power two-patch array antenna to confirm that the antenna can endure in harsh environments and sustain operation with high power microwave sources.

Figures 1 and 2 show the back view and the front view of the two-patch array antenna. The back view shows the HN connector that will be integrated to the high power RF source and the box that encloses other parts of the patch array antenna. The front view of the antenna depicts the antenna cover and flanges with four holes for securing the antenna on a platform. Figure 3 shows the detail assembly antenna architecture.

The rest of paper is as follows: Section 2 describes the experiment for the electrical test. Section 3 describes conditions and results of the vibration test. Section 4 draws conclusions.

Figure 1. Back view of the high power two-patch array antenna.

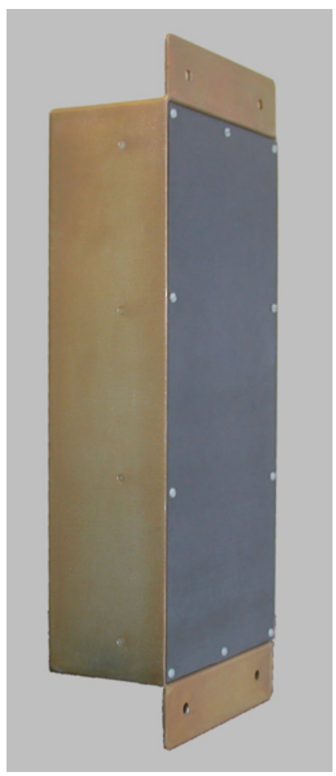

Figure 2. Front view of the high power two-patch array antenna.

Figure 3. Detailed assembly of the high power two-patch array antenna:
a. shows the cover of the antenna made of Duroid 5880 material, (b) shows ½ inch plastic spacer made of Lexan being placed between the cover and the antenna plane, (c) shows the ground plane, (d) shows the patchs of the antenna, and (e) shows the high power divider.

2. Electrical Breakdown Test

An electrical breakdown test was conducted in the anechoic chamber of Building 504 at ARL in Adelphi, MD. Figure 4 shows the setup for the high power electrical test. In this figure, the high power source was the RF source from a high power microwave system that is being used in a combat theater. A directional coupler was used to send the transmitted signal to the patch array antenna and to make a low level of power available for monitoring. A horn antenna was used to obtain the received power at the device. The output signals from the directional coupler and the horn were monitored.

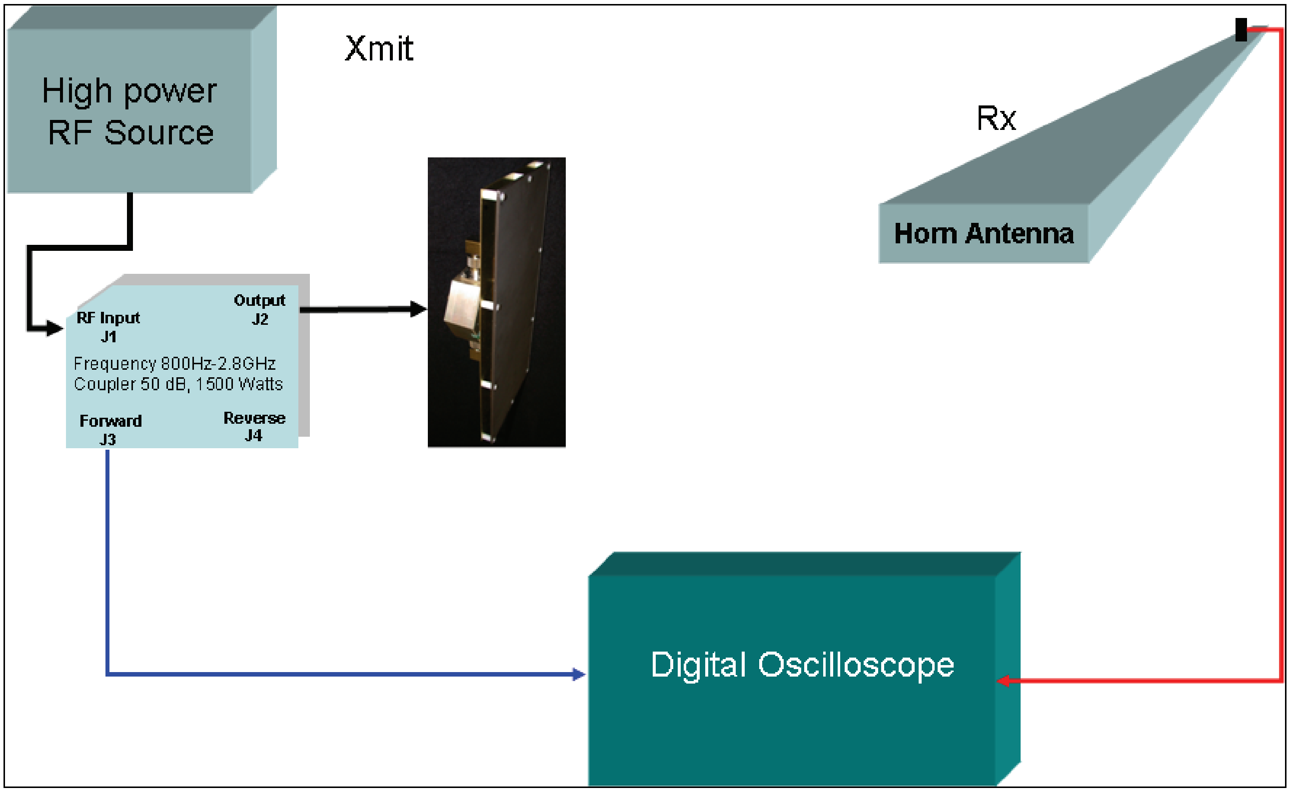

Figure 4. High power electrical test setup.

The objective of this test was to determine whether a single patch or a two-patch array antenna can handle high power RF source. One method to determine if arcing occurs is to visually analyze the input signal and received signals on the digital scope. If the arc occurs, the received signal would show a dropout in the middle of the transmitted pulse on the digital scope. If the arc did not occur, we conclude that the test was successful. For this test, we tested two antennas. The first antenna under test had a single patch with straight feed and right angle connectors. It is presumed that right angle connector would be used in a deployed system. The other antenna tested was the two-patch array antenna. Each antenna was tested at two minutes and five-minute intervals under the conditions at the peak power (> 2 KW).

Figures 5 and 6 present the electrical test data for the single patch and the two-patch array antenna, respectively. For the single patch, the top panel, figure 5(b) shows the results of the test with the straight connector. For the bottom panel, figure 5(d) shows the results of the test with the right angle connector. These results clearly show that NO arcing occurs. Similarly, for two-patch array antenna, figure 6(c) clearly indicated that NO breakdown occurs. Figure 6(a) shows the front of the two-patch array antenna. Figure 6(b) shows the back side of array antenna with a high power two-way divider.

The results as shown in those figures demonstrate that the high power patch antenna with air dielectric and with probe feed can sustain high power test even with the right angle connectors.

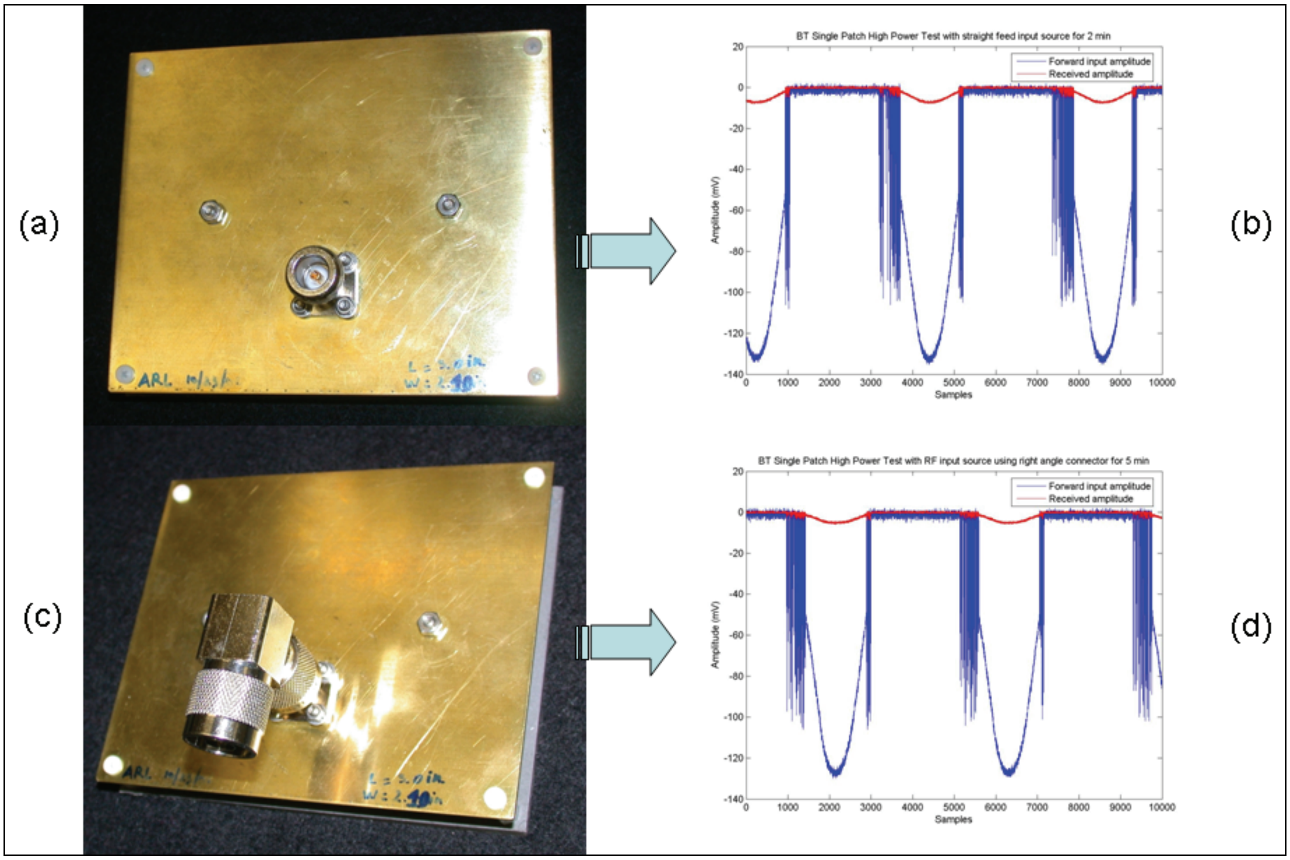

Figure 5. Electrical test results for a single patch antenna.

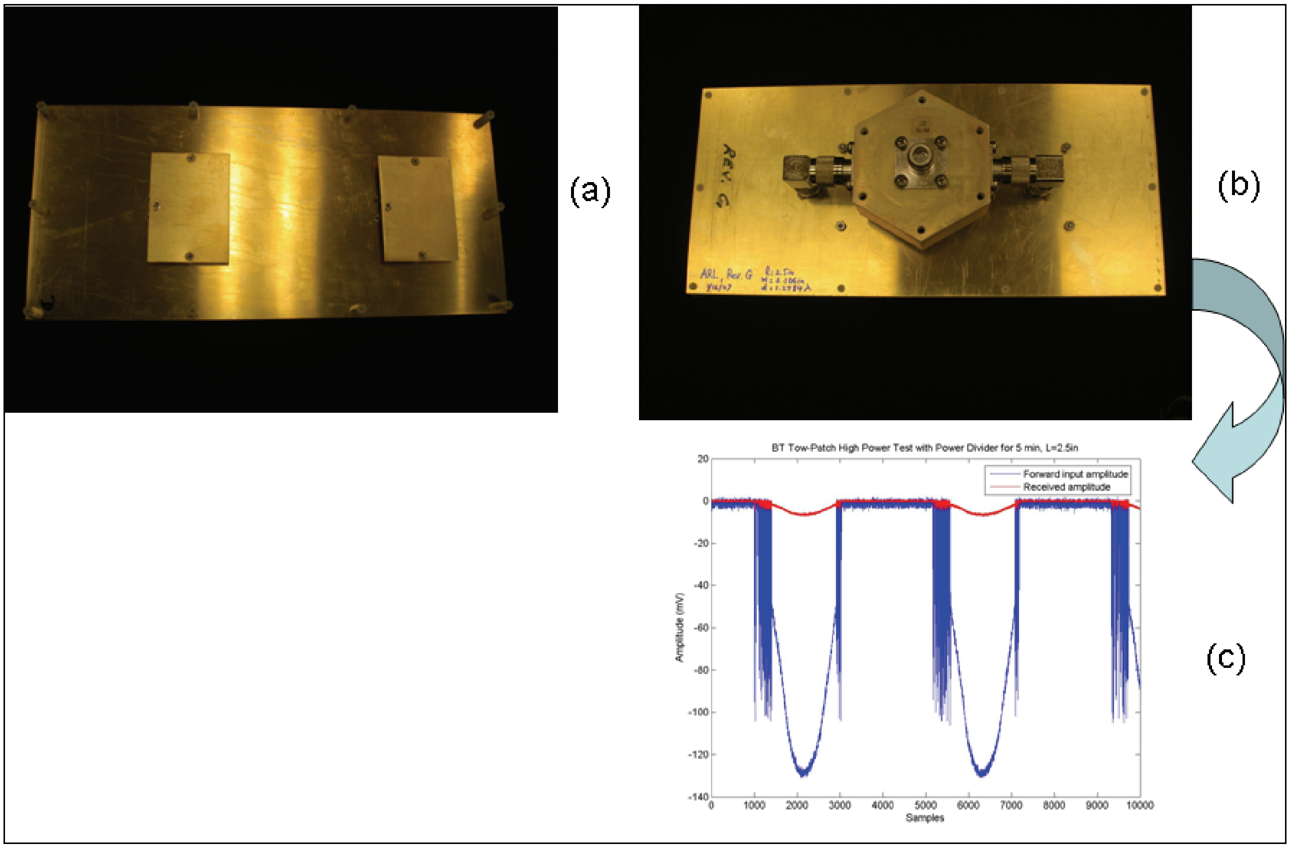

Figure 6. Electrical test results for a two-patch array antenna.

3. Mechanical (Vibration) Test

The vibration test was executed at the Army Research Laboratory, Adelphi Laboratory Center, Building 203 by Morris Berman and Mark Fellows of the Ordnance Materials Branch, Materials Division, Weapons & Materials Research Directorate. The test followed the Secured Cargo Vibration of Test Article in which the vibration spectra were derived from ITOP 1-2-601 (25Jan99) in appendix figures A-1 to A-3. The test was carried out for an equivalent of 1,000 km of tactical wheeled vehicle travel. The ITOP specifies a 40 minute test for an equivalent of 800 km. The vibration duration for this test was 50 minutes corresponding to an equivalent of 1,000 km of travel. Minor low frequency modifications to the ITOP specifications were necessary due to the performance limitations of the shakers used. The vibration test includes three separate tests: vertical, transverse, and longitudinal.

3.1 Vertical Test

Excitation equivalent to the unit's vertical direction was carried out on a horizontal slip table. The unit was tested for 1 minute, then returned to the sponsor for functional testing. The item was then subsequently vibrated for the remaining 49 minutes.

During the 1st minute, the unit was bolted directly to the slip table with four 1/4-20 bolts. In this configuration the exposed screw heads on the underside of the unit were in contact with the slip table surface. During the remaining 49 minutes and testing in subsequent directions, the unit was mounted on two 5/8" shims as pictured in figure 7. In this configuration only the ears of the unit's chassis contacted the slip table. The remainder of the back was not in contact with any other surface. A red connector plug (not shown in figure 7) was attached to RF connector (which is shown in figure 1) for the duration of this test.

Figure 8(a) shows the difference between the actual spectrum used for the testing and that defined by the ITOP. Figure 8(b) shows the control spectrum, which is identical to the "Tested Spectrum" curve in figure 8(a). Figure 8(b) also shows four response measurements made at various times during the vibration as well as the ±3 dB alarm limits and ±6 dB abort limits. Excitation equivalent to the unit's vertical direction was carried out on a horizontal slip table. The unit was tested for 1 minute, then returned to the sponsor for functional testing. The item was then subsequently vibrated for the remaining 49 minutes.

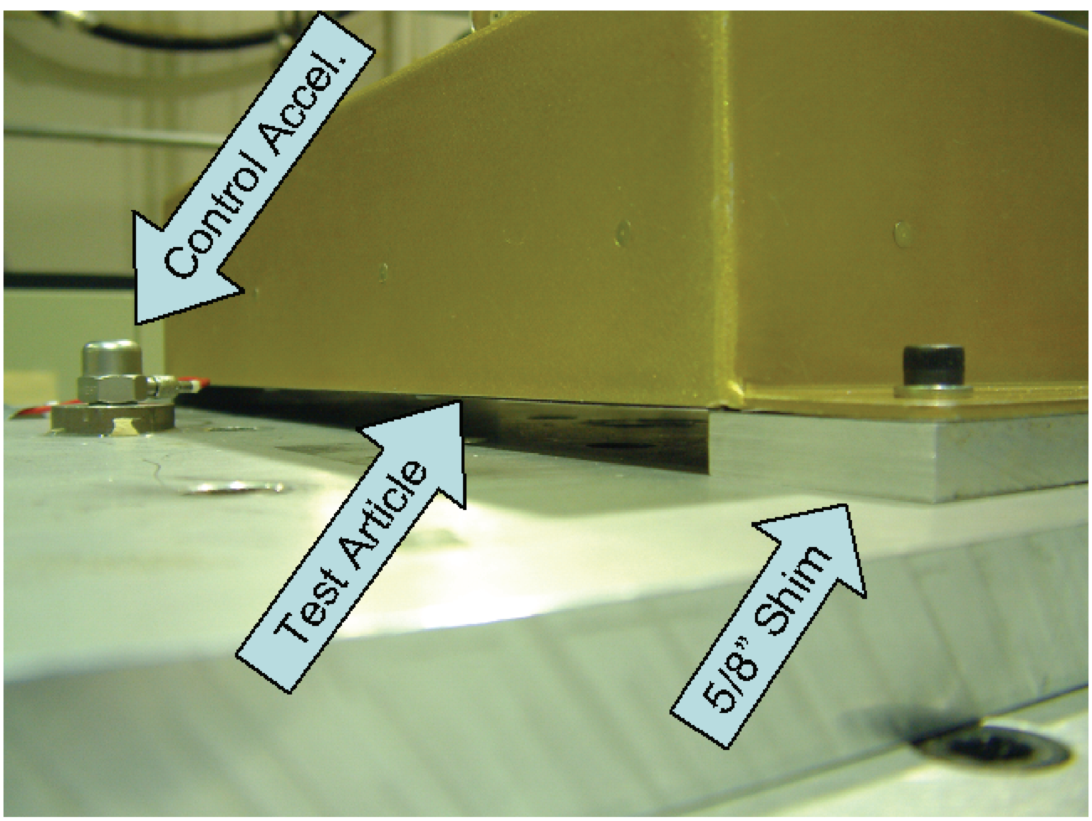

Figure 7. Test article mounting with shims.

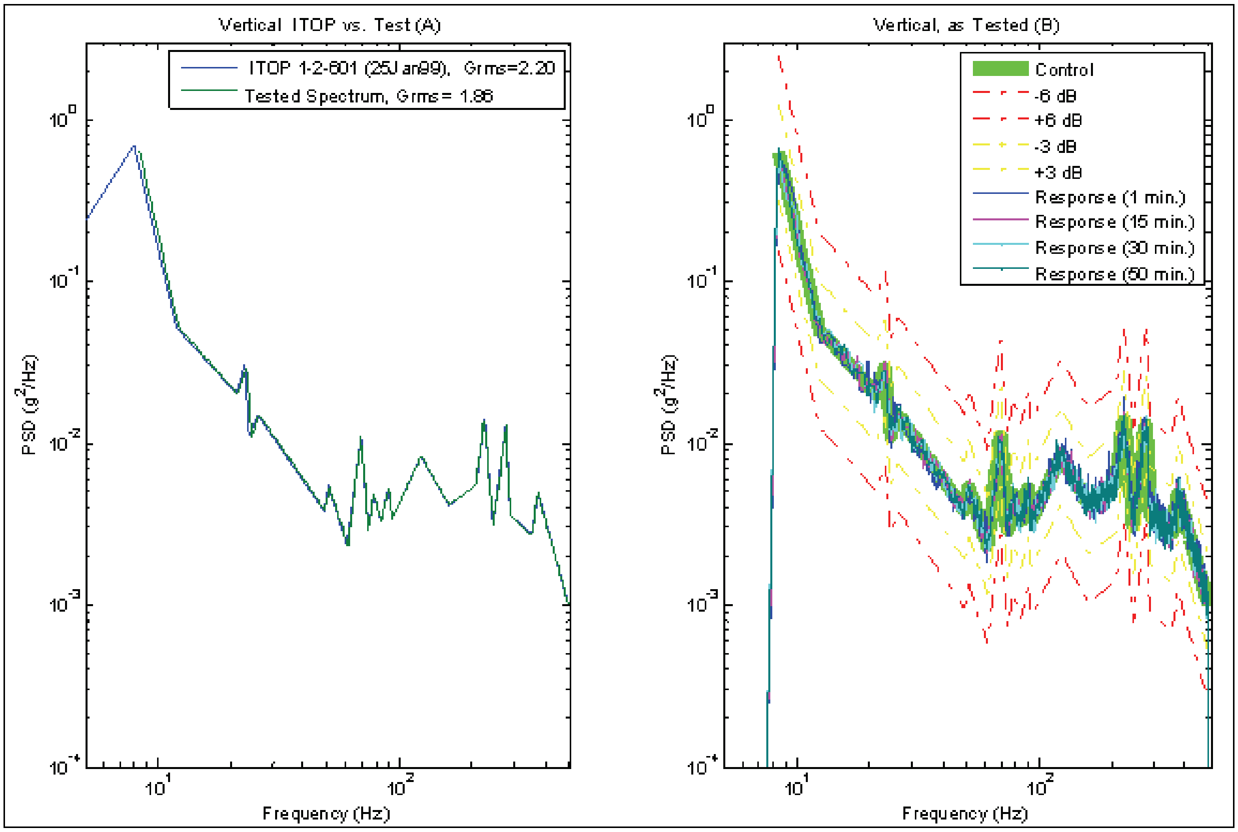

Figure 8. Vertical testing results.

3.2 Transverse Test

Excitation equivalent to the mounted unit's transverse direction was also carried out on the slip table. In this configuration, the unit was mounted with shims, as in the last 49 minutes of the vertical direction. The lower frequency portion of the spectrum had to be modified slightly to accommodate the limitations of the shaker system used for the testing. Figure 9(a) details the low frequency differences in the spectrum. Figure 9(b) shows the measured control data from 4 different points in time during the test, as well as the ±3 dB alarm limits and ±6 dB abort limits.

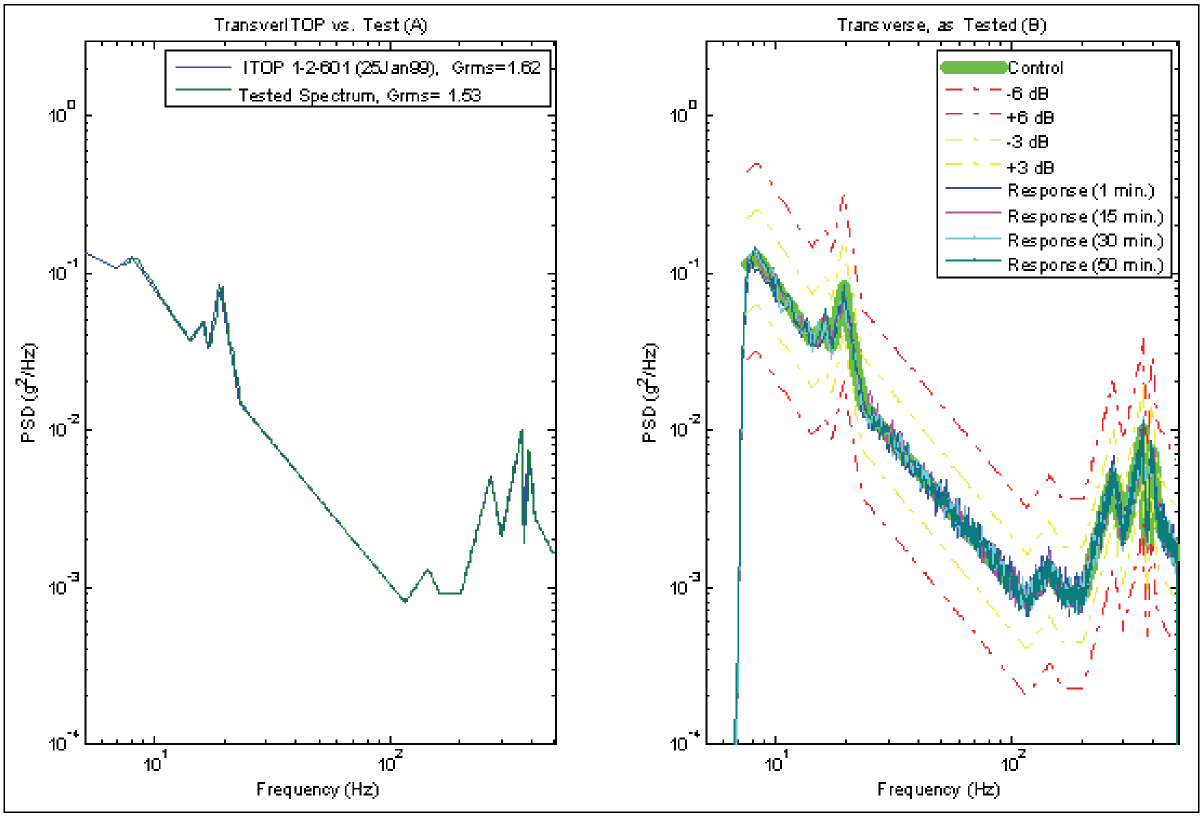

Figure 9. Transerve testing results.

3.3 Longitudinal Test

Excitation equivalent to the mounted unit's longitudinal direction was carried out on a vertically mounted shaker. In this configuration, the unit was also mounted with shims, as in the transverse testing. A 90° elbow connector was attached to the test article for the duration of this test. Figure 10 shows how the test unit was mounted for the longitudinal vibration. Figure 11(a) details the low frequency differences in the spectrum. Figure 11(b) shows the measured control data from 4 different points in time during the test as well as the ±3 dB alarm limits and ±6 dB abort limits.

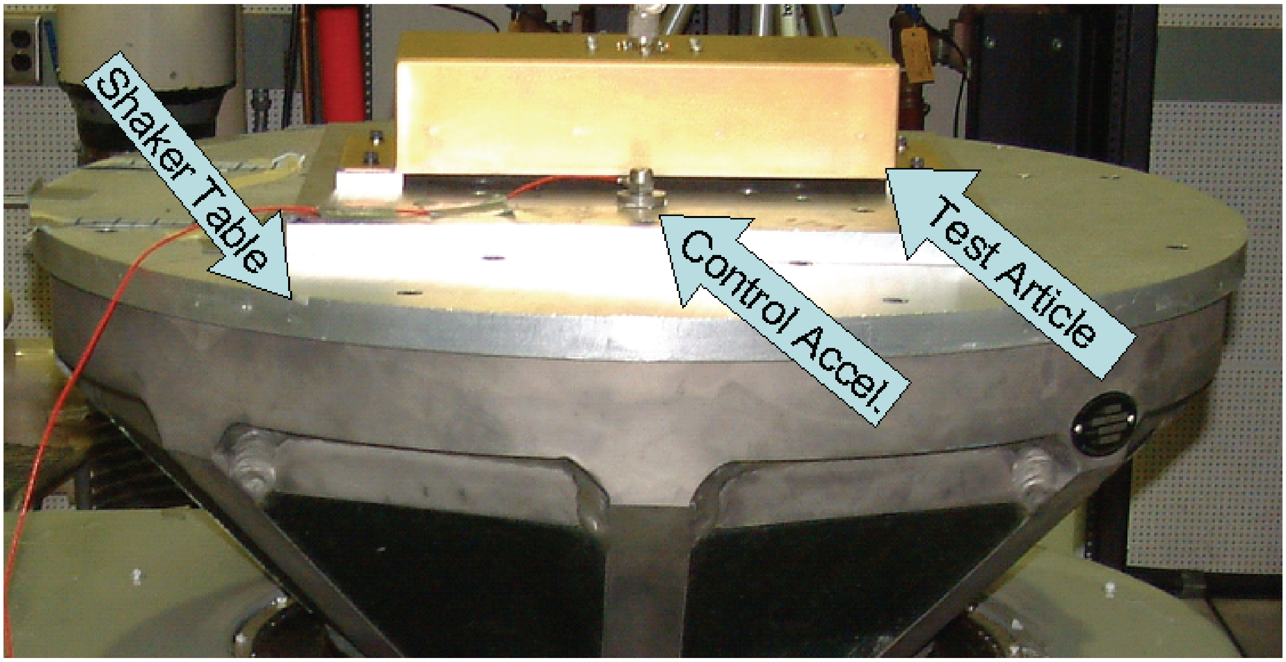

Figure 10. Longitudinal testing setup.

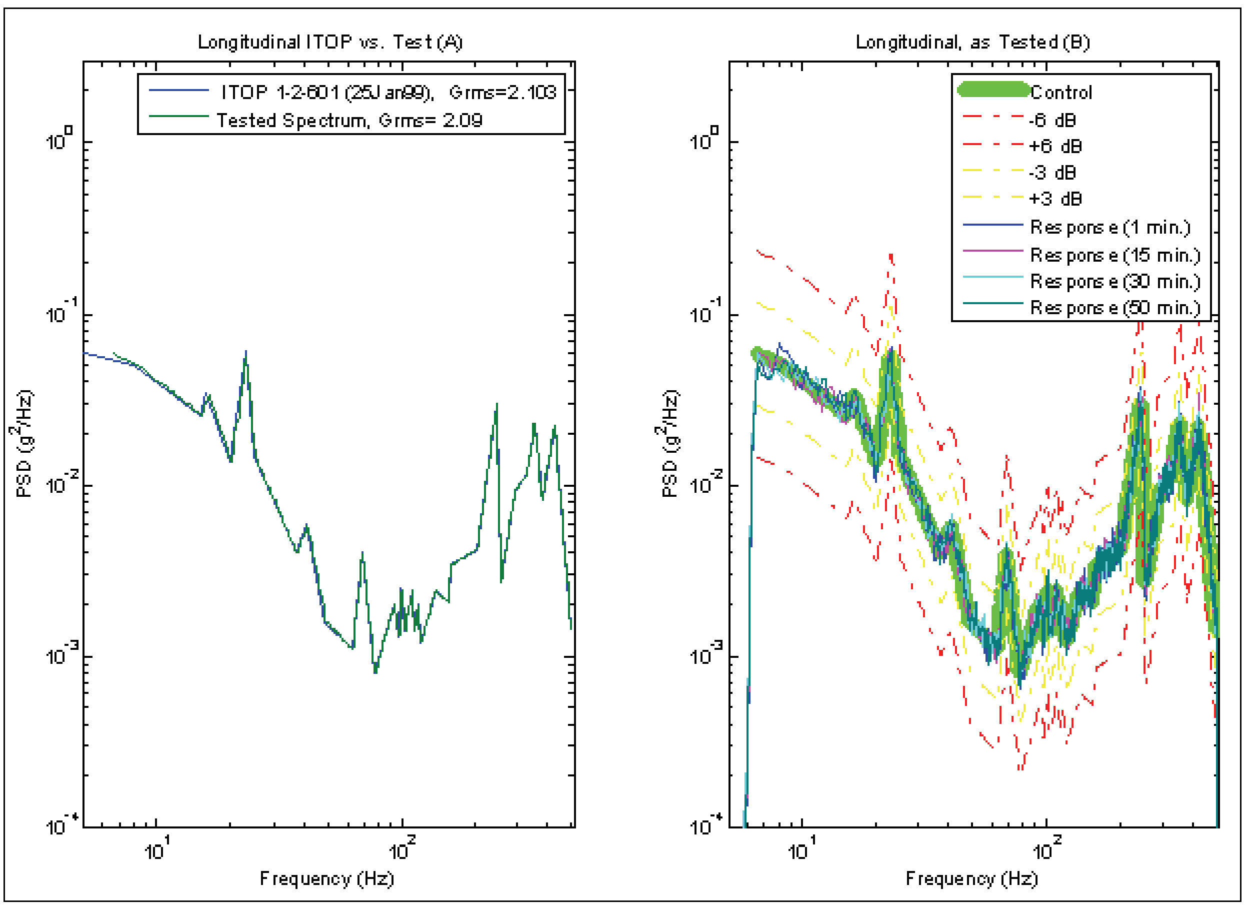

Figure 11. Longitudinal testing results.

4. Discussions

For electrical test, the high power single element antenna successfully passed high power testing as did the two patch array fed with a 2-way high-power splitter.

After the vibrational testing, the antenna still sustained the performance although the nylon screws of the antenna cover were loosened about a quarter of a turn. The right angle connectors which attached to the high power divider also loosened less than a quarter of a turn. The solution for this issue has been resolved by making the enclosure box with floating locked nuts for securing the antenna cover and the lock threading material to lock the right angle connectors.

5. Conclusions

The high power patch array antenna has been developed for purposely replacing the much larger horn antenna. This design demonstrates a low profile, high efficient patch array antenna. The antenna has undergone vigorous electrical and vibration tests.

6. References

1. Ly, C.; Weiss, S.; Harrison, A. A Novel High Power Patch Array Antenna System. Patent pending, ARL-07-18, Army Research Laboratory, ALC, submitted on 18 April 2007.

2. Weiss, S.; Coburn, K. An Efficient Patch Antenna with Bandwidth Enhancement. *Proceedings of 2007 A&P Conference,* June 2007.

3. Colburn, K.; Weiss, S.; Ly, C. Patch Antenna Modeling Issues using Commercial Software. *IEEE EMC Society*, July 2007.

Appendix. Partial ITOP 1-2-601 (25Jan99)

APPENDIX B. WHEELED- AND TRACKED-VEHICLE SECURED CARGO VIBRATION.

Figures B-1 through B-3 represent the cargo environment at the cargo bed of a composite of U.S. and German tactical wheeled vehicles. The U.S. vehicles were the M127 12-ton semitrailer, M813 and M814 5-ton trucks, M36 2-1/2-ton truck, CUCV M1009 1-1/2-ton truck, HMMWV M998 1-1/4-ton truck, and HEMTT M985 10-ton truck; the German vehicles included the following trucks: Unimog, 2-ton, MAN 5-ton, MAN 7-ton, MAN 10-ton, and MAN 15-ton. The data used for establishing these spectra were derived from measurements of the vehicles operating at various speeds over specially designed courses representing unimproved road and off-road conditions. Figures B-4 through B-6 represent the cargo environment at the cargo bed of the 1/4-ton M416 and the 1-1/2-ton M105A2 two-wheeled trailers (U.S.), and the German 1-1/2-ton two-wheeled trailer. Figures B-7 through B-15 represent the 10 ton M985 HEMTT (US), 5 ton M813/814 truck (US) and the M998 HMMWV (US). Again the spectra were established from measurements on the two-wheeled trailers operating over the same specially designed courses. These spectra are broadband random with peaks and notches at various discrete frequency bands. The break points of the peaks and notches are given for establishing the spectra shapes. Excitation shall be applied through the three major axes of the test item.

Table B-3 presents the vibration environment at the cargo bed of the M548 tracked vehicle. These spectra were derived from measurements on the vehicle while operating at various speeds on a paved road. The schedules consist of a flat low-level broadband random excitation across the total frequency spectrum with higher level narrowbands of random excitation superimposed on the broadband environment. The narrowbands of random energy are from the track-laying patterns and are vehicle speed related and are swept simultaneously across the total frequency bandwidth of the applicable narrowband at the specified bandwidth and sweep rate. Excitation shall be applied through the three axes as described above. The transport distance and associated test duration given in Table B-1 represent a one-time movement through the transport scenario defined in Figure A-1. A determination of the number of transport scenarios to be simulated must be made during test planning to ensure proper mileage simulation.

The acquisition and processing of data for all the vehicles are documented in References j and m.

During laboratory testing, the vibration control accelerometers should be located on the mounting platform as close as possible to the test load.

Figure A-1. Reference B-1.

Table B1. Time Schedules For Vibration Of Items Transported As Mission/Field Secured Cargo.

Transport mode	Figure #	Page #	Transport Distance-km	Test Duration
Tracked Vehicle	Table B-3	B-4	25	60 minutes per axis
Wheeled Vehicles	Figure B-1	B-5	800	40 minutes per axis
	Figure B-2	B-6	800	40 minutes per axis
	Figure B-3	B-7	800	40 minutes per axis
Two-wheeled Trailers (See NOTE.)	Figure B-4	B-8	50	32 minutes per axis
	Figure B-5	B-9	50	32 minutes per axis
	Figure B-6	B-10	50	32 minutes per axis
M985 HEMTT 10 Ton Truck	Figure B-7	B-11	800	40 minutes per axis
	Figure B-8	B-12	800	40 minutes per axis
	Figure B-9	B-13	800	40 minutes per axis
M813/814 5 Ton Truck	Figure B-10	B-14	800	40 minutes per axis
	Figure B-11	B-15	800	40 minutes per axis
	Figure B-12	B-16	800	40 minutes per axis
M998 HMMWV Cargo Bed	Figure B-13	B-17	800	40 minutes per axis
	Figure B-14	B-18	800	40 minutes per axis
	Figure B-15	B-19	800	40 minutes per axis

NOTE: This is the maximum distance of travel in the two-wheeled trailer from Figure A-1, Appendix A. If the tracked vehicle (M548) is used, this transport distance and corresponding test duration should be reduced by 50 percent.

The actual field vibration levels have been exaggerated in order to reduce the laboratory test times. The individual exaggeration factors used are presented in Tables B-2 and B-3. If the user determines that the selected test times are unacceptable, the actual field levels may be exaggerated to a greater extent using the procedures discussed in ITOP 1-1-050[1].

Figure A-2. Reference B-2.

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23 April 1998

Table B-2. Test Exaggeration Factors For Vibration Of Items Transported As Mission Field-Secured Cargo.

Transport Mode	Exaggeration Factor
M985 HEMTT	1.85
M813/814	1.85
M998 HMMWV	1.85
Composite Wheeled Vehicle	1.85
Two-wheeled Trailer	1.00
Tracked Vehicle	0.69*

NOTE: If ammunition is destroyed or damaged beyond safe and effective use during test, reduce exaggeration factors and annotate test records.

* Since test time would have been only approximately 4.8 minutes at the exaggeration factor of 1, test time could not be properly accommodated by existing software for narrowband random-on-random type lab test. For additional guidance and background information consult ITOP 1-1-050, Appendix A, page A-6, paragraph 4.c, (1), (2), and (3).

B-3

Figure A-3. Reference B-3.

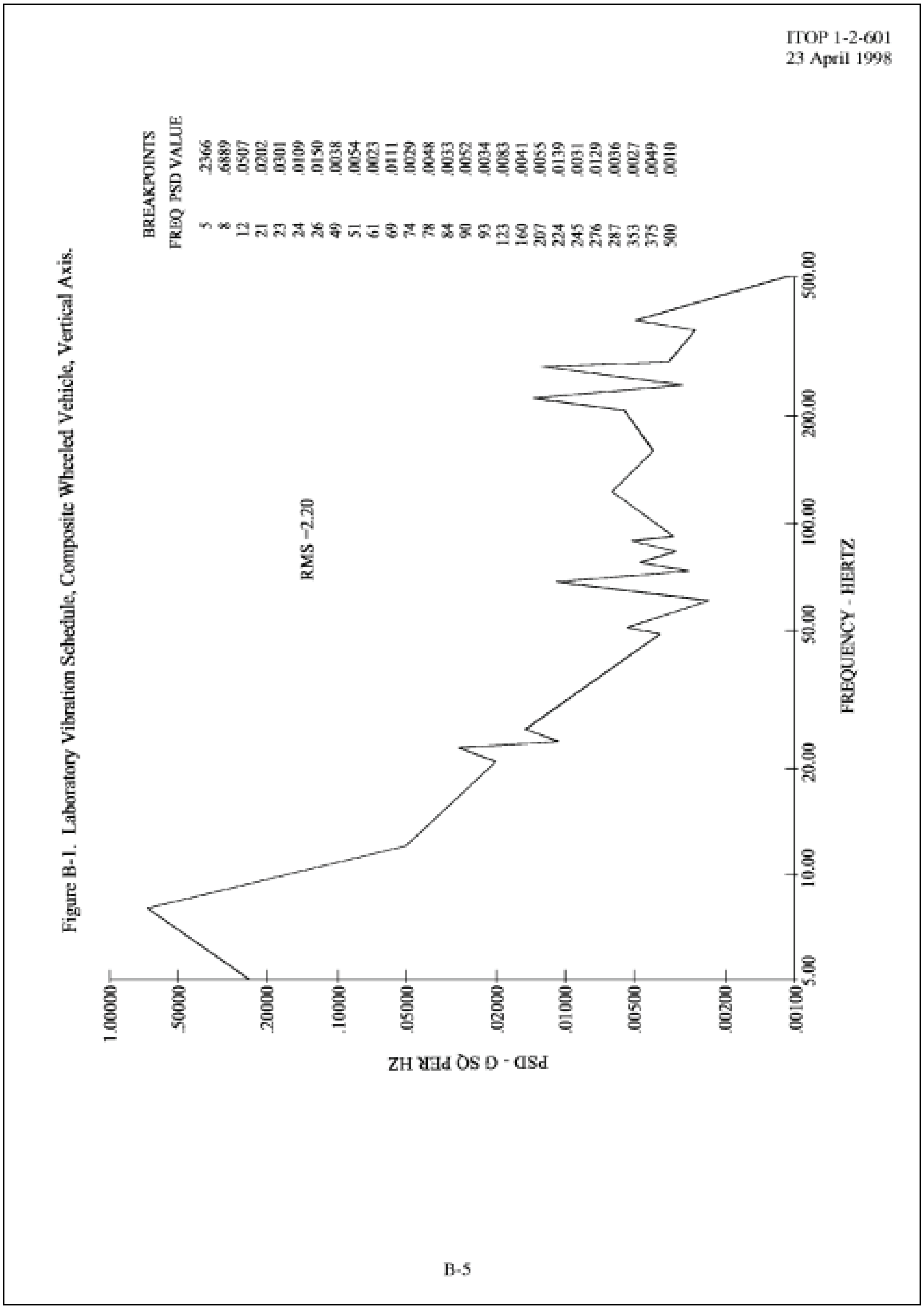
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Figure B-1. Laboratory Vibration Schedule, Composite Wheeled Vehicle, Vertical Axis.

BREAKPOINTS

FREQ	PSD VALUE
5	.2366
8	.6889
12	.0507
21	.0202
23	.0301
24	.0109
26	.0150
49	.0038
51	.0054
61	.0023
69	.0111
74	.0029
78	.0048
84	.0033
90	.0052
93	.0034
123	.0083
160	.0041
207	.0055
224	.0139
245	.0031
276	.0129
287	.0036
353	.0027
375	.0049
500	.0010

B-5

Figure A-4. Reference B-5.

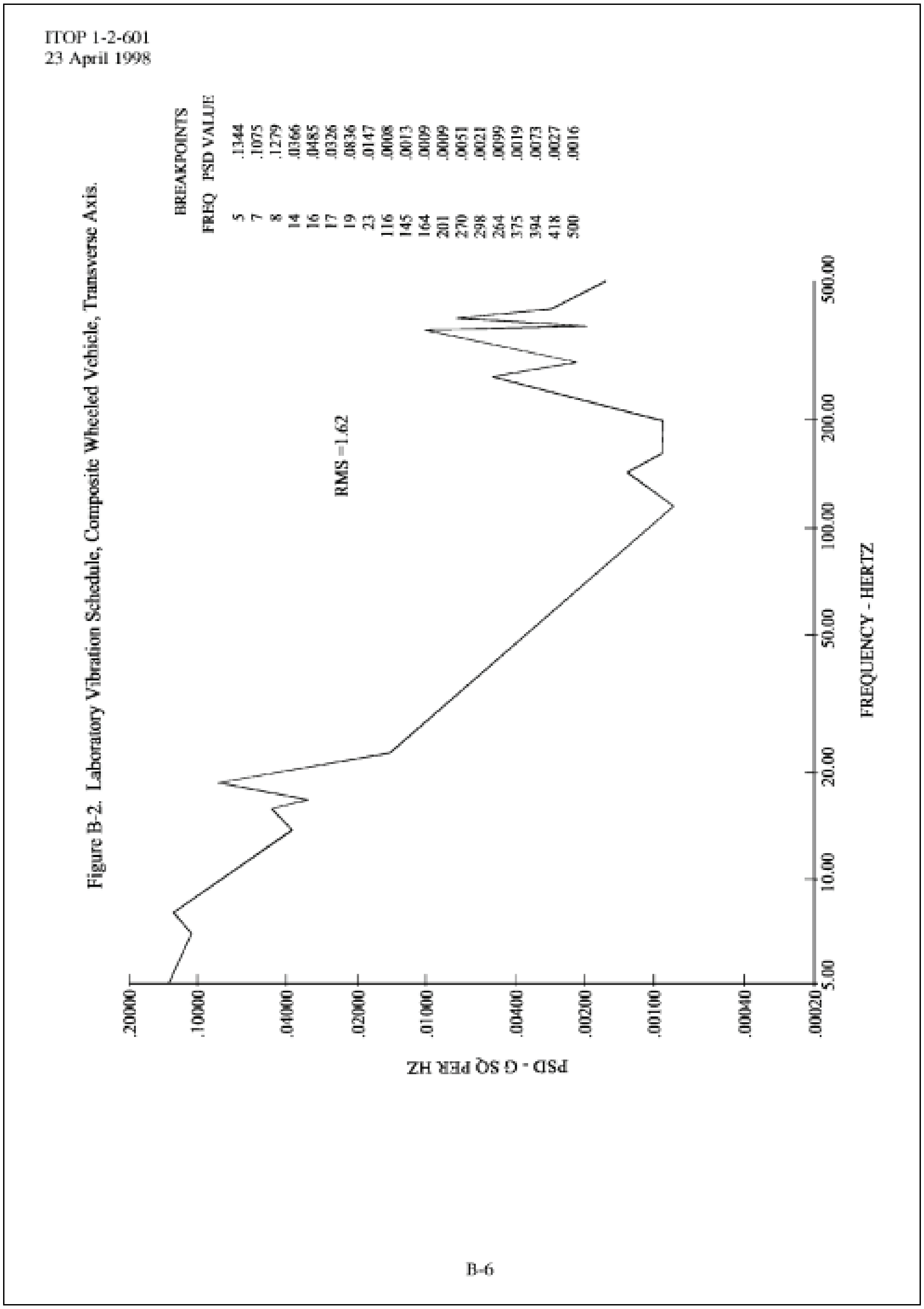

Figure A-5. Reference B-6.

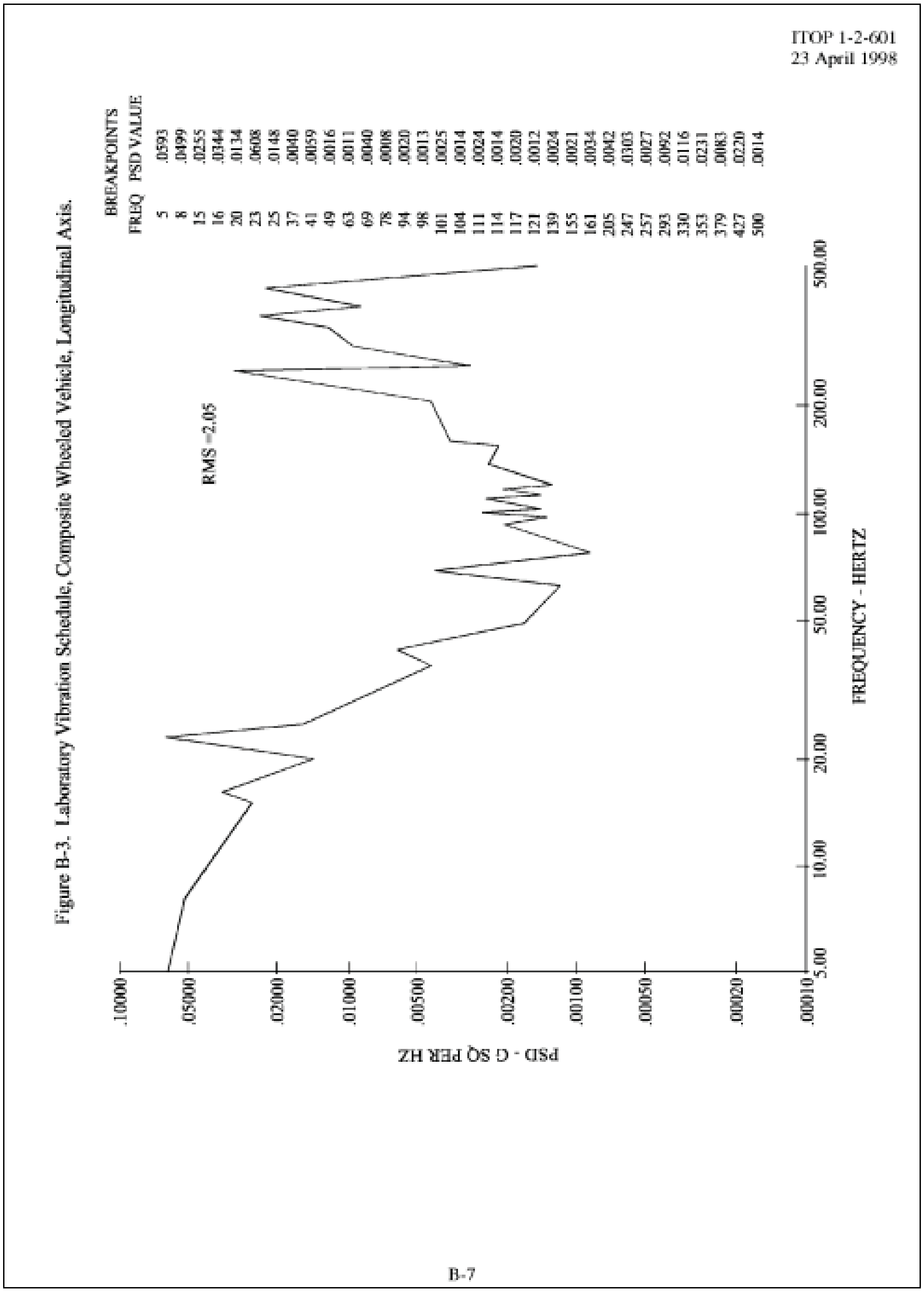

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Figure B-3. Laboratory Vibration Schedule, Composite Wheeled Vehicle, Longitudinal Axis.

BREAKPOINTS	
FREQ	PSD VALUE
5	.0593
8	.0499
15	.0255
16	.0344
20	.0134
23	.0608
25	.0148
37	.0040
41	.0059
49	.0016
63	.0011
69	.0040
78	.0008
94	.0020
98	.0013
101	.0025
104	.0014
111	.0024
114	.0014
117	.0020
121	.0012
139	.0024
155	.0021
161	.0034
205	.0042
247	.0303
257	.0027
293	.0092
330	.0116
353	.0231
379	.0083
427	.0220
500	.0014

B-7

Figure A-6. Reference B-7.

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